## REMARKS

On an initial note, Applicant wishes to thank the Examiner for pointing out the informality regarding listing the current status of Application Serial No. 09/755,221 in the specification, and the informality regarding claim 29. The specification and claim 29 have been correspondingly corrected. Further, during a telephone conversation with Examiner Piziali on 6/1/2004, a provisional election was made to prosecute the invention of Species 2, claims 30 and 37, claims 29 and 36 being generic. Claims 26-28, 31-35, and 38-42, are correspondingly withdrawn from further consideration by the Examiner, thus canceled without traverse and without prejudice, as being drawn to a non-elected invention.

Claims 29 and 36 have been amended. Support for the amendments to the elements of claim 29 can be found on Application page 4, lines 9-10; page 4, lines 21-23; and page 4, lines 15-16 and the abstract, respectively. Support for the amendments to the elements of claim 36 can be found on Application page 3, line 29 to page 4, line 1; page 3, lines 9-10 and original claim 10 of U.S. Patent Application Serial No. 60/231,245, filed September 8, 2000 (now abandoned); and page 4, lines 15-16 and the abstract, respectively.

The Applicant submits that these minor amendments and corrections herein are made without prejudice as to patentability, including the doctrine of equivalents, and no new matter has been added.

### Claims 29-30 and 36-37 Satisfy 35 U.S.C. § 112, First Paragraph

The Examiner rejected claims 29-30 and 36-37 under 35 U.S.C. § 112, first paragraph, as containing subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor at the time of application was filed had possession of the claimed invention. Applicant respectfully traverses the rejection. The originally filed written description and/or Figures provide sufficient support or suggestion for the subject claims, as currently amended. The Examiner stated that "Claims 29 and 36 claim a pair of outer skins each formed from composite layers . . . [and that the] specification is silent regarding "composite layers." The Application, however, provides that "[s]kin or laminate 12 is formed by

stacking *layers* or piles 11 of fibrous reinforcing material [(page 3, line 29 to page 4, line 1)] . . . . [and that the] laminate or skin is formed from *composite* material [and may be] . . . formed using prepeg material, unimpregnated fibrous material, and combinations of these two [(page 2, lines 4-5)]." Thus, "composite layers" or "composite material" is fully supported.

**Claims 29-30, and 36-37 Satisfy 35 U.S.C. § 112, Second Paragraph**

The Examiner rejected claims 29-30 and 36-37 under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention, stating that "in claims 29 and 36, it is not clear how the structural component is 'adapted to be cured within a mold.'" The Applicant respectfully traverses the rejection. The Application provides that "the skin or laminate 12 of Figure 1 is created by laying layers or piles 11 into the surface of a tool 21 that represents half of a matched die [(page 4, lines 15-16), and that the] . . . [t]wo skins or laminates are created by laying the cut-to-shape piles into a matched mold, with over-woven or over-braided mandrels or similar tooling details placed between the skins [(Abstract)]. Thus, "adapted to be cured within a mold" is fully supported. Nevertheless, Applicant has removed the "adapted to" terminology. Further, the Applicant has removed the "tubular configuration" terminology.

**Claims 29-30, and 36-37 Are Not Anticipated**

The Examiner rejected claims 29-30 and 36-37 under 35 USC § 102(b). The Applicant respectfully traverses the rejection.

The French Patent 1,262,381 ("Parsons") discloses a two-piece mold and a process for molding wings constructed with a reinforced shroud. Applicant has made a translation of the reference to and is enclosing it. All page number references with respect to Parsons will be made with respect to the translation. Referring primarily to page 5, lines 5-35, of the translation, the process includes placing lower coating sheets (53) (fiberglass sheets without fluid plastic material) on to the molding's lower half, positioning lower triangular mandrels (44) *shrouded* with reinforcing fabric (51) *wrapped* around and attached by a wire (Figure 6) around the mandrels (44). *See also*, translation page 1, para. 2, providing only one example of the type of reinforcing material

utilized, that being fiberglass; page 4, line 51, identifying lower sheet (53) as being fiberglass fabric; page 4, lines 26-28, identifying the material placed on a lower molding as woven reinforcement fabric (without a fluid plastic material) and identifying the material shrouded around the mandrels as layers of reinforcing fabric woven around the mandrels; and page 4, lines 39-40 and 46-47, identifying the *shroud* (51) as having a *flat* design as shown in Figure 7, attached to mandrel (44) by a wire (Figure 6).

Claim 29 (as amended) claims a structural component in an intermediate stage when the component is preferably located within a mold. Layers 11 that make up outer skins 12 include collimated fibers supported by a sparse number of transverse fibers. The composite layers that make up the inner supports or socks 41 (Figure 4) are braided or woven to conform to the shape of one of the mandrels. Claim 36 (as amended) also claims a structural component in an intermediate stage when the component is preferably located within a mold. Layers 11 that make up outer skins 12 include layers of fibrous reinforcing composite material. Also, in this claim the mandrels 5 are enclosed by composite socks 41 formed of a fabric that is braided or woven into an elongate tube (structural channel).

A claim is anticipated only if each and every element as set forth in the claim is found, either expressly or inherently described, in a single prior art reference, whereby the identical invention must be shown in as complete detail as is contained in the claim.

Specifically, regarding claim 29 (as amended), there is no mention of the structure of the Parson's weave. Parsons does not disclose that either of the lower or upper coating sheets (53), (54), include a layer of collimated fibers supported by a sparse number of transverse fibers. Thus, Parsons does not teach or suggestion collimated fibers in the skins. Also, there is no mention that the Parson's shroud (51) is woven or braided to conform to the shape of the mandrel (44). Parsons teaches to wrap a flat cloth around the mandrels and not to use an inner support woven or braided to conform to the shape of the mandrel.

The Applicant in the Application on page 4, lines 8-11, draws a clear distinction between woven and unidirectional/collimated fibers. It is known in the art that unidirectional/collimated fabrics are different from what the art terms as a woven fabric. In the art, the terms unidirectional/collimated and woven are mutually exclusive when referring to a fabric type. The

structural qualities of a woven fabric are vastly different than that of a fabric formed of unidirectional or collimated fibers. A woven fabric has interlacing threads of the weft and the warp.[1] Due to its interlacing nature, woven fabric has significant bends, which in some applications can cause an undesirable structural weakness not found in fabrics composed of unidirectional or collimated fibers. Unidirectional/collimated fabric has fibers oriented in the same (parallel) direction,[2] generally, having a sparse number of transverse fibers, if any, generally to allow for transport of the structure prior to curing.

Regarding claim 36 (as amended), there is no mention in Parsons that either of the lower or upper coating sheets (53), (54), are formed from layers of fibrous reinforcing composite material; or that the shroud (51) is made of a plurality of composite socks tightly enclosing each of the mandrels, or that such socks are braided or woven into an elongate tube or sleeve. As stated with respect to claim 29, no mention is made of the structure of the Parson's weave. There is no teaching or suggestion that the shrouds (51) around the mandrels (44) are a plurality of composite socks, enclosing each of the mandrels. They are in fact shrouds (sheets) of flat material (51) wrapped around mandrel (44) and secured by a wire (Figure 6).

Thus, Applicant respectfully requests the Examiner withdraw the rejection. Further, regarding claims 30 and 37, Parsons does not teach or suggest layers of the outer skins are pre-cured and the socks around the mandrels uncured. Parsons does not teach or suggest any moment in time in a pre-cured phase of formation of its structure where both the lower and upper coating sheets (53), (54), are positioned together to form a pre-cured structure and the shrouds uncured. Rather the upper and lower sheets and the shrouds are cured simultaneously. *See* page 5, lines 17-20 and 26-30. Thus, there is no such teaching or suggestion.

**Claims 29-30, and 36-37 Are Not Obvious**

The Examiner rejected claims 29-30 and 36-37 as being unpatentable over U.S. Patent No. 5,469,686 to Pikiet in view of French Patent Application No. 1,262,381 to Parsons. The Applicant

[1] The American Heritage® Dictionary of the English Language, Third Edition copyright © 1992 by Houghton Mifflin Company. Electronic version licensed from InfoSoft International, Inc. All rights reserved.
[2] *See* http://www.compositesworld.com/sb/glossary, page 23.

respectfully traverses the rejection. To establish a *prima facie* case of obviousness, the prior art references (when combined) must, and do not, teach or suggest all the claim limitations.

Pykiet discloses structurally reinforced panel member formed by wrapping one or more sheets (224) of a curable composite material around extruded mandrels (222). *See* col. 2, lines 20-37. Referring to col. 2, lines 35-37 and 42-50, the specification states that "[t]he mandrels are preferably extrusions made of aluminum which are braided, filament wound or applied by fiber placement." The specification further states that "[e]ach of the [extruded] mandrels is preferably wrapped three times . . . [with] . . . quartz pre-peg material."

Regarding claim 29 (as amended), like Parsons, there is no mention in Pykiet that either of the lower or upper sheets (212), (232) include a layer of collimated fibers supported by a sparse number of transverse fibers. No mention is made of the actual structure of the Pykiet sheets (212), (232), and thus, there is no teaching or suggestion of a structure including such a layer of collimated (parallel) fibers supported by a sparse number of transverse fibers. Also, there is no mention that the Pykiet sheet (224) is fabric woven or braided to conform to the shape of one of the mandrels (222). Pykiet teaches to wrap the flat sheet (224) three times around mandrel (222) and not to use an inner support woven or braided to conform to the shape of the mandrel.

Regarding claim 36 (as amended), like in Parsons, there is no mention in Pykiet, and thus, no teaching or suggestion that the sheets (224), which are *wrapped* three times around the mandrels, are a plurality of composite *socks* tightly enclosing each of the mandrels or that each stock is characterized by being braided or woven into an elongate tube. Forming socks 41 which can slip over the mandrels 5 is a significant improvement over shrouds which must be wrapped around the mandrels and secured using a device such as a wire or sheets which may require multiple wraps, as described in Parsons and Pykiet, respectively. Thus, neither Parsons nor Pykiet teach or suggest such a feature.

Thus, Applicant respectfully requests the Examiner also withdraw this rejection. Also, claims 30 and 37, dependent upon claims 29 and 36, respectively should also be allowed.

**CONCLUSION**

In view of the amendments and remarks set forth herein, Applicants respectfully submit that the application is in condition for allowance. Accordingly, the issuance of a Notice of Allowance in due course is respectfully requested.

Respectfully submitted,

Date: October 17, 2004

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INDUSTRIAL PROPERTY DEPARTMENT

# PATENT OF INVENTION

P.V. No. 832,753 No. 1,262,381

International Classification: B 29 c – B29 d

**Two-piece mold for molding wings or structural shapes of layered, reinforced, hollowed plastic materials.**

Company termed: PARSONS CORPORATION, domiciled in the United States of America.

**Applied for on July 12, 1960, at 14:45 in Paris**

Issued via decree dated April 17, 1961.

*(Bulletin Officiel de la Propriete Industrielle – "Official Bulletin of Industrial Property"*, No. 21, 1961)

This invention concerns the use of two-piece or complementary molds to make objects with hollow structures, such as lifting or bearing surfaces or structurally shaped wings with a reinforcement mesh; and it particularly applies to complementary two-piece molded devices that include mandrels or internal cores, in terms of size, and to processes for molding structural shapes made of plastic materials, reinforced by fabric, with the use of said mold.

Up to now, we have not used two-piece molds in general to mold structurally-shaped wings. To the contrary, reinforcing material, such as fiberglass, was coated and impregnated with a fluid plastic resin, then molded against a single molded surface (either male or female) by a fluid under pressure, for example, beginning with an empty sac.

In molding wing shrouds, with thin walls presenting a thin reinforcement mesh subject to standards governing the uniform resistance and weight of aircraft structures, a difficult problem arises that has not been resolved satisfactorily until now. All wall and mesh thicknesses must be minutely adjusted, as must the ratio of the plastic material to the reinforcing material, as well as its distribution within and upstream of the reinforcing material.

This invention makes it possible to resolve these problems. In addition, it proposes to provide:

Molds consisting of complementary half-molds and inner mandrels that are self-adjusting in their positions within the interior of the molds, thus providing the shroud's desired thicknesses and volumes;

Transversal reinforcement molding, precisely formed;

A means to permit the use of mandrels that are automatically positioned during the course of molding tapered, lifting/bearing or winged surfaces;

A procedure for molding objects made of plastic material that is reinforced by permeable sheets for reinforcement purposes, to obtain a regular distribution of the plastic material on and around the material, enabling the mandrels used in the hollow objects to be positioned correctly under the pressures created by molding; so as to be able to form a transverse reinforcement mesh within these molded objects.

The previous practice of molding stratified wings with the aid of a fabric made of fiberglass and of fluid plastic resins necessitated the wetting, separated by the fluid plastic material of each sheet or shroud of fiberglass fabric, to the extent it was placed within the molding or around a mandrel. However, in order to reach significant, acceptable fabric-to-resin ratios, the mass of resin that is added to that of the fabric makes it difficult, if not impossible, to shroud the mandrels by means of such a wet fabric, sufficiently narrow and tightened so as to obtain perfect alignment and separation of the fabric's laminas. Likewise, it becomes more difficult to previously position these mandrels shrouded in the wetted state during the complementary mold halves, and to install them in-place; particularly when it is necessary to adjust a large number of triangular mandrels of slight tolerances between the complementary mandrel halves.

To overcome these difficulties, and to attain the goals mentioned above, as well as others that will be cited hereinafter, the requester supplies an equipment item and a process which shall be described below, referencing the designs per annex, in which:

Figure 1 is an exploded perspective view of the upper and lower complementary mold halves, representing certain gudgeons employed with the latter;

Figure 2 is a perspective view of the set of mandrels employed in the mold halves of Figure 1;

Figure 3 is a section following Line 3-3 of Figure 1, representing the halves of the mold in Figure 1, with the set of mandrels in Figure 2 placed into position.

Figure 4 is a section analogous to that in Figure 3, following line 4-4 in Figure 1:

Figure 5 is a perspective view of a mandrel, presenting a means for terminating the mesh near the end of the wing's base;

Figure 6 is a perspective view of a typical mandrel, shown as shrouded in a fiberglass fabric.

Figure 7 is the drawing developed in the two-dimensional plane, concerning the fiberglass fabric shroud shown in Figure 6;

Figure 8 is a perspective view of the lower half of the mold, on which are deposited layers of fiberglass fabric and in which are installed a series of shrouded mandrels; and

Figure 9 is a perspective view of a wing after molding, representing a molded attachment base console, which is intended to be introduced there.

Referring now to the drawings, a lower half has been provided, designated as (11) in general, and an upper half of the mold, designated as (12) in general, that are formed in any general fashion, such as from hard laminated wood, whose platform is larger than the wing that is to be molded to it. The lower mold half (11) includes a concave cavity surface (13) which conforms to the contour of the outer surface of the wing that is to be molded, on one side of its chord; and the mold's upper half (12) presents a concave cavity surface (14), conforming to the form of the wing on the other side of its chord. The cavities, (13) and (14), present flat marginal portions (15) to the outside and in the vicinity of their edges, which correspond to the edges leading to and away from the wing. The corresponding marginal portions (15) of the upper and lower molds are mutually parallel and, once the mold halves are united, are separated from each other by a sufficient distance to receive the edges of the material that is to be molded there.

As shown in Figure 1, the surfaces (13) (14) of the concave cavity taper off in the direction of an edge of the upper and lower halves (11) (12) of the mold, to form a smaller wing at its extremity than at its base. The lower surface (13) of the concave cavity terminates at this edge, at a surface belonging to the extremity (16) of the molding (to form an extremity of the wing according to a right section) and rises perpendicularly to the lower surface (13) of the concave cavity. The form of the surface of the extremity (16) corresponds to that of the section of the wing's extremity. This surface (16) is the internal surface of a bloc at the end of the mold, generally designated by (17), which is sectioned along the upper edge so as to correspond to a continuation in the direction of the extremity of the upper surface (14) of the concave cavity. Thus, the end portion of the molding device is closed, except for the discharge grooves (18) arranged transversally at the upper edge of the molding's end block (17).

The mold's lower and upper halves (11) (12) present edges of blocks (19) that are used in aligning and tightening the mold halves to each other, and which extend beyond the flat marginal parts (15) that delimit the cavity's contour surfaces (13) (14). The block edges (19) present a series of vertical, sleeved bores (20) used to arrange the molding halves (11) (12) into alignment, one after the other, maintaining alignment through the use of an alignment gudgeon (21) installed in each of the aligned vertical bore sets (20).

When the block edges (19) of the upper and lower molding halves are tightened against each other, they serve to establish the molding's internal height between the concave cavity's structurally shaped surfaces (13) (14), at the desired height, to determine the wing's thickness.

We employ simple tightening methods, as determined by practice, to apply pressure between the molding halves (13) (14). As an example of such a tightening device, the alignment gudgeon's (21) extremities may contain thread, nut and washer (22) (23) (24).

Near the basal end of the cavity's lower surface (13), the molding's lower half (11) is equipped with a channel (25) that constitutes an extension (26) in the direction of the base of the lower half (11) of the molding. The upper half (12) of the molding presents an overhanging part (27) in the direction of the base; and aligned vertical bores (28) are provided, for example, between the channel (25) and the overhang (27) in the immediate vicinity of the base edges of the cavity's surfaces (13) (14). The vertical aligned bores (26) /sic/ are provided stop gudgeons (29) that are constructed and located so that their median portion abuts against the base extremities of the mandrels, which shall be described below.

On the outside of the channel (25) to the lower extension (26), in the direction of the base, the lower half (12) of the molding is fitted with a block (30) of positioning gudgeons, presenting a series of steps with a horizontal surface (31) along the upper surface, each of them presenting a vertical bore (32) of positioned gudgeons. The elements (32) of the positioning gudgeons receive positioning gudgeons (33) from the base of the mandrel, and can be equipped at their upper ends by transversal gudgeons (34) so they be easily drawn.

The block (17) of the molding extremity is traversed by horizontal bores (35), and receives a positioning gudgeon (36) from the ends of the mandrel, which may display construction identical to that of the positioning gudgeons (33) at the base of the mandrel. The layout of the end block's bores (35) will be described below.

The mandrels that constitute the set represented in Figure 2 can also be made of laminated hardwood. As is seen from a comparison of Figure 2 with Figures 1 and 9, the mandrels shown are tapered and are mutually complementary; and, when arranged within the interior of the molding halves (11) (12), jointly provide the precise spaces that are necessary to ensure the tapered wing's conformation, as designated in a general sense by *a* on Figure 9, so that its upper and lower surfaces, *b, c,* respectively, its vertical mesh *d* and its diagonal reinforcement mesh *e*, can be formed with precise tolerances. Mesh *d* and *e* supply the desired spaces within the wing's interior *a*: the form and volume of the mandrels to be described correspond in general to the form and volume of these desired spaces.

Each of the mandrels of the set represented in Figure 2 presents a mandrel body generally designed as 37, which extends from the molding's end block (17) over a length that is at least equal to the length of the span of the cavity in molding halves (11) (12); and the body in fact can be made slightly longer so as to reach the end of the base of the cavity, to abut against the mid part of the vertical stop gudgeon (29) that is provided for it, as shown in Figures 3 and 4. Each of these mandrel bodies (37) presents a longitudinal steel reinforcement (38) that includes a part (39) jutting out from the end of the base and that has, in the vicinity of its outer edge, a vertical bore (40) so spaced as to be capable of alignment with and above the corresponding vertical bore (32) of the positioning gudgeon, set in the block (30) as represented in Figures 3, 4 and 8. The bore (40) has a diameter that is sufficiently greater than that of the positioning gudgeon (33) from the base and from the mandrel that is adjusted to it, so as to enable the reinforcement (38) to "abut" vertically on the latter, with a certain degree of freedom.

As represented in Figure 2, the mandrels generally designated as (37) include a mandrel (41) for the leading edge and a mandrel (42) for the trailing edge, both of which have a markedly triangular transversal section. In order to achieve the triangular wing construction represented in Figure 9, the greater number of mandrels located between the mandrels (41) of the leading edge and (42) of the trailing edge also contain a triangular transversal section. Each of these markedly triangular intermediate mandrels is located either near the upper wall or the lower wall of the wing represented in Figure 9, which is slightly shaped to provide the hollow wing contour depicted. Thus, the mandrels consisting of large surfaces, or bases, presented near the upper surface (14) of the concave cavity, and which present peaks near the lower surface (13) of the concave cavity, are designated by upper triangular mandrels (43). In corresponding fashion, the generally triangular mandrels that present large surfaces or bases near the lower surface (13) of the concave cavity, and the peaks near the upper surface (14), are matched by lower triangular mandrels (44).

In providing connections to affix the wing *a,* the diagonal reinforcement mesh is omitted, beginning with two spans *f* and *g;* the mandrels provided for these spans present a markedly trapezoidal transversal section and are designated by reference number 45.

It is considered advantageous to arrange the ends of certain mandrels (37) relative to the molding's end (17) block. Thus, mandrel 41, of the leading edge, mandrel 42, of the trailing edge, each of the lower triangular mandrels (44) and each of trapezoidal mandrels (45) are fitted at their ends with a horizontal bore (46), relative to the corresponding horizontal bore (35), so that a gudgeon at the end (36) that is introduced through the end bore (35) is able to project into the end of each of these mandrels, and to position it. These mandrels, whose ends are thus positioned, can nonetheless freely "float" in an inclined fashion toward the top to the basal end, and with reference to this play between the vertical bore (40) and the gudgeon (33). Nonetheless, each of the triangular upper mandrels (43) is free at its end. This freedom that characterizes the triangular upper mandrels (43) (which alternate in a general fashion among the mandrels, whose ends are installed in a fixed manner) allows the upper mandrels (43) to adjust freely, vertically along their entire length and, at the same time, in oblique fashion while inclining, and also oscillating within the plane of a chord around their gudgeons, which position the mandrel base. This inclination and oscillation are of slight amplitude, even though significant relative to the tolerances allowable in the wall and the mesh that constitutes the wing *a* represented in Figure 9.

The positions relative to an upper triangular mandrel (43) and a lower triangular mandrel (44) between the molding halves (11) (12) are shown in Figures 3 and 4, taken at the posts in the direction of the chord that corresponds to two of the steps adjacent to the horizontal surface (31) and to the positioning gudgeon block (30).

Thus, the lower triangular mandrel (44), which occupies the greater part of the space within the molding cavity in the section shown in Figure 3, is affixed at its end by a horizontal gudgeon (36) in its bore at the end (46); but then, it can float independently upward and downward at its basal end. On the other hand, the upper triangular mandrel (43) which occupies the greater part of the molding cavity in the section represented in Figure 4, even though it is affixed in an analogous manner at its basal extremity, is not affixed to its end and, thus, is able to adjust, through an oblique movement, perpendicularly to the plane of the section shown in Figure 4. This has made it possible, to a remarkable degree, to adapt the mandrels, each with respect to the others and relative to the cavity of the molding, so as to obtain efficient adjustment of the action of the fiberglass structure and the resin that is to be molded in the spaces contained among them.

In comparing the set of mandrels represented in Figure 2 with the fully molded wing structure shown in Figure 9, and, in particular, relative to the major span *f* shown at the base of Figure 9, the width relative to the chord of the *f* span is equal to the width of the trapezoidal mandrel (45) at the surface, in the direction of the chord or "base" of the adjacent upper mandrel, designated by (43), and shown alone in perspective in Figure 5, looking from the summit located within the wing's interior surface. Near the base of the mandrel (43), the diagonal surface (47) presents a thicker part of the step (48); in analogous fashion, the upper surface (49) (as shown in Figure 2), presents a step (50). The steps (48) and (50) have thicknesses equal to those of the diagonal or reinforcement mesh *e* and of the vertical mesh respectively, which are provided in a general sense as a reinforcement within the wing's interior *e*, shown in Figure 9. Inasmuch as these steps (48) and (50) make it possible to eliminate the diagonal and vertical mesh, *e, d* respectively, only in the area limited to the steps, an expansion of the span *f* is encountered, to a width greater than that of the trapezoidal mandrel (45) alone. At its base, span *f* receives the fill-in unit from the base *h*, which is joined adhesively to the span *f* after the wing *a* is molded. The *h* fill-in unit's main function is to provide a means of attachment for the wing *a* and, for this purpose, it presents a cylindrical attachment bore *i*.

The molding process, with wings constructed with a reinforced shroud according to this invention, consists, in general, of arranging the layers of a woven reinforcement fabric (without a fluid plastic material) on a lower molding half, shrouding layers of reinforcing fabric woven around cores or mandrels, adding a quantity of fluid plastic material on the latter and arranging the layers of reinforcement fabric, which are woven so as to abut against the molding's upper half. As a final stage, the molding halves are tightened together in complementary fashion, to establish an inner height for the molding and produce a previously determined internal volume. Thus, the fluid plastic material is extruded for the purpose of distributing it across, between and around layers of the reinforcing fabric, which is woven so as to allow penetration of all of its interstices. A certain amount of the plastic material must be obtained, exceeding the quantity that is necessary for the desired ratio of fabric to the plastic material. Pressure extrudes the excess amount through evacuation bores (18) and out the end of the base of the molding.

We may now describe the particular method for implementing this process, by utilizing the elements of the moldings represented in the drawings;

Each molding body can be shrouded through the use of a permeable reinforcing material, such as the fiberglass fabric that shrouds the mandrel (51), and can be attached by a wire as shown in Figure 6. The shroud, made of fabric, preferably is made a bit larger than necessary. After the shrouding is completed, it is trimmed at its extremities, to the mandrel's dimensions. In order to form and reinforce the wing-tip, the excess tissue is trimmed from the mandrel's two sides. This, left in a projecting form from the other side of the mandrel, is trimmed to form a triangular cover for the tip (52). To facilitate the arrangement within the molding, it preferably consists of a continuation of the molding (51) on the lower side of the mandrel (37). The shrouding that is trimmed in this manner presents a flat design that is markedly like that shown in Figure 7.

Regarding the stepped mandrel (43), the fabric shroud is trimmed at the basal end to terminate at steps 48 and 50; and the mandrels' fabric shrouds located near these steps are trimmed in analogous fashion, at this location.

Sheets of fiberglass fabric, designated as lower surface sheets (53), are trimmed to cover the lower surface (16) of the concave cavity and are directed upward against the surface of the molding end (17), extending to the upper edge of the molding end block (17). Following the chord's direction, these sheets of fiberglass extend into the flat, marginal parts (15), and cover them. The sheets that cover the upper

surfaces (54) are trimmed to extend, in analogous manner, in the same direction as the chord, to cover the entire rear portion (14) of the concave cavity, as well as the flat marginal parts (15) at their leading and trailing edges, to then rejoin the end part that is directed to the upper part (55) of the lower shrouding sheets (53).

The lower coating sheets (53) are carefully placed onto the molding's lower half, in the dry state, together with their end parts, and are directed upward (55) and arranged against the molding's end surface (16). The lower triangular mandrels (44), shrouded as shown in Figure 6, are arranged on the lower covering sheets with their end- covering parts (52) directed upwards and installed there; and the positioning gudgeons (36) are introduced through bores (35) of the end block so as to pierce the portions covering the end (22) of the coating sheets (53), and penetrating the bores (46) of the mandrel ends. Each of these lower triangular mandrels (44) is affixed by the part jutting out at the basal end (39) of its steel reinforcing element (38), in block (30) of the positioning gudgeon, by means of a basal positioning vertical gudgeon (33).

At this stage, it may also be convenient to place, on the lower coating sheets (53), the leading edge mandrel (41), the trailing edge mandrel (42) and the trapezoidal mandrels (45) shrouded in fabric, and to affix them in place in an analogous manner at their basal and end extremities.

A quantity of fluid plastic resin, with a syrupy consistency, is then poured in a generalized manner over the lower coating sheets (53) and on the mandrels that were placed on the latter. The upper triangular mandrels (43) (and one or the other of the other mandrels which have yet to be placed on the lower coating sheets (53) are then placed into position.

The upper triangular mandrels (43), as represented, are not equipped with mandrel end bores (46). They are laid down in their position in a clearly alternating manner, placed upon the other mandrels and on the fluid plastic material which can be found on the latter, in the positions which they are able to freely occupy; and the jutting parts (49) at the basal end of their steel reinforcing elements (38) are affixed by a gudgeon in block (30), in analogous manner.

When the entire quantity of the fluid plastic material that is to be utilized has been poured onto the mandrels within the molding interior (either in total at a single time or progressively as the mandrels are installed) the upper coating sheets (54) are installed so as to extend in the direction of the chord between the flat, marginal parts 15 at the molding cavity's leading and trailing edges, and to extend from the base of the latter to its end.

According to one variant, it is possible to provide coating sheets within the mandrel's inner half, from the trailing edge, which can extend forward toward the wing's leading edge and around the latter, and be directed onto the mandrel, and the plastic material is employed in forming the upper surface coatings.

By virtue of the tapered form of the mandrels and the molding's cavity, one proceeds to the next, additional stage: the upper half (12) of the molding is installed with regard to the molding's lower half (11), the sleeved vertical bores (20) are aligned, each relative to the other, and the alignment gudgeons (21) are introduced into the sleeved vertical bores. Nonetheless, before tightening the molding's halves (11) and (12), a stop gudgeon (29) is introduced into each of the pairs of aligned vertical bores/reams for the stop gudgeons (28) so that their mid portions are strictly adjusted against the basal ends of each of the mandrel's bodies (37). The molding halves (11), (12) are then drawn, each against the other, by a tightening method, such as, for example, by tightening by threading, nut and washer (22), (23) and (24) of the alignment gudgeons. The fluid pressure generated by this tightening within the molding tends to extrude or charge each of the tapered mandrels toward the outside and the basal ends; the fact that the latter abut against the stop gudgeons (29) prevents the mandrels from effecting this lengthwise displacement and avoids the tendency by the vertical bores (40) of the basal extremities (39) of the steel reinforcements to jam against the positioning gudgeons (33).

The molding then is achieved and completed in the customary manner, for the specific plastic molding resin employed, which may consist simply of allowing the resin to harden. One then opens the molding halves (11), (12), withdraws the tapered mandrels (37) and removes the mounted object, then deburrs the coating edges extending into the flat marginal parts (15). Finally, the longest spans *f* and *g* are provided filling units affixed by an adhesive, such as for the *h* filling unit.

It appears that the syrupy consistency of the plastic resin and the limitation inherent in the multiple thicknesses of the fabric, and in the narrow spaces provided between the adjacent mandrels and the molding's shaped, sectional surfaces, together ensure that the entire system maintains pressure in the fluid, in response to that of the mandrels, regulating their position in order to reach an equilibrium. This equilibrium tends to establish a constant ratio, in the molded structure as a whole, in the resin and in the fabric. Thus, for the possible ratios of plastic resin to the fabric, the thicknesses of the coatings and the mesh are adjusted by establishing the number of thicknesses/layers of the fabric existing in each wing area, by dry shrouding the mandrels and arranging them to ensure their freedom between the molding halves, then allowing the mandrels to adjust their positions in order to achieve a uniform distribution of the resin in response to the force exerted on the molding's complementary halves.

Naturally, the invention is not limited to the manner of implementation that is described and represented, and can receive numerous variants that are consistent with the spirit and framework of the invention.

SUMMARY

A. This consists of a process for utilizing a molding device made of two complementary halves, including an upper half, a lower half and a series of internal mandrels extend in the span's direction, to form wings of reinforced, stratified plastic material with an inner mesh, a procedure that is characterized by the following points, either separately or in combination;

1. It consists of arranging for a previously determined number of layers, made of a permeable reinforcement material, over the lower half of the molding to separately shroud the mandrels through the use of a previously determined number of layers made of the permeable reinforcement material, arranging the shrouded mandrels to align with the direction of the chord, relative to the material constituting the lower half of the molding, with the addition of a certain quantity of fluid plastic material to the shrouded mandrels, applying, from above, a previously determined number of layers of permeable reinforcing material, then assembling the molding's upper half, which is previously determined relative to the lower half, tightening it in the presence of the plastic material so as to distribute it under a cross fluid pressure, between and around the beds made of reinforcement material, employing this fluid pressure to adjust the positions of the inner mandrels relative to the molding's upper and lower halves, and the first relative to the others, then hardening the material in order to form a molded object and remove the object from the molding device;

2. In utilizing a molding device made of two pieces, that are mutually complementary and include a tapered upper molding half, a tapered lower half including an end part at its smallest extremity and a series of internal mandrels arranged in the direction of the span. Said process consists of arranging a layer of permeable reinforcement material onto the lower half of the molding, through the use of a layer of material that is sufficient to cover the inner surface of the molding's end portion, so as to direct it against the latter, so as to separately shroud the mandrels with layers made of the permeable reinforcing material, which projects sufficiently over a surface at the end of each mandrel in order to cover the end, arranging the shrouded mandrels in line with the direction of the chord of the material composing the lower half of the molding, with the material at the end of the mandrel being pressed against the upwardly-directed material in the end portion of the molding, blocking the basal ends of the molding, when it encounters a longitudinal movement outside the molding, adding a certain quantity of fluid plastic material over the shrouded mandrels, providing a layer of permeable reinforcement over the latter, assembling the upper half of the molding in a position determined previously relative to the lower half, and tightening it against the resistance provided by the fluid plastic material;

3. The mandrels present a triangular transverse section and are aligned in the direction of the chord, on material composing the lower half of the molding for the external lateral surfaces of a first group of triangular mandrels, that are shrouded so that the peaks of the mandrels extend away from the molding's lower half, then, near the mandrels, a second group of triangular shrouded mandrels is arranged in an alternating series, so that their peak is near the lower half of the molding and their lateral outer surfaces are directed upwards.

B. A molding device with two complementary halves for the wings, including a lower half of a structurally-shaped molding, an upper half of a structurally-shaped molding, a means associated with the molding halves so as to establish the desired internal height of the molding, a means of tightening that applies pressure on the molding halves, and internal mandrels whose form and volume correspond to the

desired empty spaces within the interior of the wings, a device characterized by the following points, either separately or in combination:

1.The mandrels present means to place them freely into position, to adjust their position so as to equilibrate the internal pressure existing within the molding.

2. The mandrels present a generally triangular section and peaks toward the interior, near the internal surface of the molding's structurally shaped interior surface;

3. The positioning means include extensions of mandrels that extend beyond the profiled molding halves, at one extremity of the latter, with each extension presenting a transversal bore and a gudgeon passing through the latter;

4. The molding halves define a cavity that tapers from a larger basal extremity toward a smaller end extremity, and the internal mandrels taper correspondingly;

5. Abutments are provided at the basal extremity in order to maintain the installation in the direction of the mandrels' spans, counter to internal pressure prevailing within the molding.

Company termed: PARSONS CORPORATION
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For the sale of the publication, write IMPRIMERIE NATIONALE 27, rue de la Convention, Paris (15°).

# Composite Materials Glossary

By: Staff

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

## A

**A-stage** - An early stage of polymerization of thermosetting resins in which the material is still soluble in certain liquids and fusible. (See also B-stage, C-stage.)

**Ablative** - Describes a material that absorbs heat through a decomposition process called pyrolysis at or near the exposed surface.

**Accelerator** - Chemical additive that hastens cure or chemical reaction.

**Addition** - Polymerization reaction in which no byproducts are formed.

**Additives** - Ingredients mixed into resin to improve properties.

**Adhesive** - Substance applied to mating surfaces to bond them together by surface attachment.

**Amorphous** - Polymers with no crystalline component.

**Angle-ply laminate** - Any balanced laminate consisting of plies at angles of plus and minus theta, where theta is an acute angle with the principal laminate axis.

**Anisotropic** - Not isotropic. Exhibiting different properties when tested along axes in different directions within the material.

**Aramid** - Aromatic polyamide fibers. (Often

referred to as Kevlar, DuPont's trademark.)

**Areal weight** - Weight of a fiber reinforcement per unit area (width times length) of tape or fabric.

**Aspect ratio** - Ratio of length to diameter of a fiber.

**Autoclave** - Closed vessel for applying fluid pressure, with or without heat, to an enclosed object.

**Autoclave molding** - Molding technique in which an entire assembly (lay up and tooling) is placed into an autoclave and subjected to heat and elevated pressure for consolidation and/or curing while removing entrapped air and volatiles.

**Automated tape laying** - Fabrication process in which prepreg material, typically unidirectional tape, is laid across the surface of a mold in multiple layers and directions by an automated tape-application machine to form a structure.

**Axial winding** - Filament winding wherein the filaments are parallel or at a small angle to the axis of rotation.

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## B

**B-stage** - Intermediate stage in the polymerization reaction of some thermosets in which the material softens with heat and is plastic and fusible but does not entirely dissolve or fuse. The resin of an uncured prepreg or premix is usually in this state. (See also A-stage, C-stage.)

**Bag molding** - Molding technique in which the composite structure is placed in a rigid mold and covered with a flexible impermeable layer of film and the edges sealed, followed by consolidation and/or curing with pressure applied by vacuum, autoclave, press or inflation of the bag.

**Balanced laminate** - Any laminate that contains one ply of minus theta orientation with respect to the principal axis of the laminate for every identical ply with a plus theta orientation.

**Basket weave** - Woven reinforcement where two or more warp threads go over and under two or more filling threads in a repeat pattern; less stable than the plain weave but produces a flatter, stronger, more pliable fabric.

Batch - Material made by the same process at the

same time having identical characteristics throughout. Same as lot.

**Bias fabric** - Fabric in which warp and fill fibers are at an angle to the length.

**Biaxial fabric** - Fabric with two non-interwoven layers - a unidirectional warp (0°) layer and a unidirectional weft (90°) layer - which are bonded together, usually by through-the-thickness stitching, to form a single sheet of fabric. (See also triaxial fabric, quadraxial fabric.)

**Biaxial winding** - Filament winding wherein helical bands are laid in sequence, side by side, with no fiber crossover.

**Bidirectional laminate** - Laminate with fibers oriented in more than one direction on the same plane.

**Bismaleimide (BMI)** - Type of thermoset polyimide that cures by an additional reaction, thus avoiding formation of volatiles. Exhibits temperature capabilities between those of epoxy and polyimide.

**Bleeder cloth** - Layer of woven or nonwoven material, not a part of the composite, that allows excess gas and resin to escape during cure.

**Bleedout** - Excess liquid resin appearing at the surface of the composite structure, particularly during filament winding.

**BMI** - See bismaleimide.

**Bond ply** - Ply or fabric patch that comes in contact with the honeycomb core during repair.

**Bond strength** - As measured by load/bond area, the stress required to separate a layer of material from another material to which it is bonded; the amount of adhesion between bonded surfaces.

**Boron fiber** - Fiber produced by chemical vapor deposition of boron onto a core material, usually a tungsten-filament. Because of the deposition process, a boron fiber is of a fairly large diameter, typically about 0.4 mils, and is thus often referred to as a wire.

**Braiding** - Textile process that intertwines into a pattern three or more strands, yarns or tapes, typically into a tubular shape.

**Breakout** - Separation or breakage of fibers when the edges of a composite part are drilled or cut.

**Breather** - Loosely woven material that does not come in contact with the resin but serves as a continuous vacuum path over a part in production.

**Broadgoods** - Fibers woven into fabrics that may or may not be impregnated with resin; usually furnished in rolls.

**Buckling** - Failure mode usually characterized by unstable lateral deflection rather than breaking under compressive action.

**Bundle** - General term for a collection of essentially parallel filaments.

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## C

**C-stage** - Final step in the cure of a thermoset resin, resulting in irreversible hardening and insolubility. (See also A-stage and B-stage.)

**CAD/CAM** - Computer-aided design/computer-aided manufacturing.

**Carbon fiber** - Reinforcing fiber produced by the pyrolysis of an organic precursor fiber, such as PAN, rayon or pitch, in an inert environment at temperatures above 1,800°F. The term carbon is often used interchangeably with the term graphite, but the fibers differ. Carbon fibers are typically carbonized at about 2,400°F and contain 93 percent to 95 percent carbon. Carbon fibers can be converted to graphite fibers by graphitization at 3,450°F to 4,500°F, after which they contain more than 99 percent elemental carbon. Carbon fibers are known for their light weight, high strength and high stiffness.

**Carbon/carbon** - Composite of carbon fiber in a carbon matrix.

**Catalyst** - Substance that promotes or controls curing of a compound without being consumed in the reaction. (See also hardener.)

**Caul plate** - Plate or sheet the same size and shape as the composite lay-up with which it will be used. The caul plate is placed in immediate contact with the lay-up during curing to transmit normal pressure and provide a smooth surface on the finished part.

**Ceramic-matrix composites (CMC)** - Materials consisting of a ceramic or carbon fiber surrounded by a ceramic matrix, primarily silicon carbide.

**Chemical vapor deposition (CVD)** - Process in which the reinforcement material is deposited from the vapor phase onto a continuous core such as boron or tungsten.

**Circumferential winding** - Process of winding fiber perpendicular to the axis during filament winding.

**Cloth** - See fabric.

**CMC** - Ceramic-matrix composite.

**Cocured** - Cured and simultaneously bonded to another prepared surface.

**Coefficient of thermal expansion (CTE)** - A material's fractional change in length for a given unit change of temperature.

**Cohesion** - Tendency of a single substance to adhere to itself. Also, the force holding a single substance together.

**Coin tap** - Tapping a laminate with a coin in different spots to detect a change in sound, indicating the presence of a defect that may require repair.

**Commingled yarn** - Hybrid yarn made with two types of materials intermingled in a single yarn (for example, thermoplastic filaments intermingled with carbon filaments to form a single yarn).

**Composite** - Three-dimensional combination of at least two materials differing in form or composition, with a distinct interface separating the components. Composite materials are usually manmade and created to obtain properties that cannot be achieved by any of the components acting alone.

**Compression molding** - Technique for molding thermoset plastics in which a part is shaped by placing the fiber and resin into an open mold cavity, closing the mold, and applying heat and pressure until the material has cured or achieved its final form.

**Compressive strength** - Resistance to a crushing or buckling force, the maximum compressive load a specimen sustains divided by its original cross-sectional area.

**Condensation** - Polymerization reaction in which simple by-products (for example, water) are released.

**Consolidation** - Processing step that compresses fiber and matrix to reduce voids and achieve a particular density.

**Contaminant** - Impurity or foreign substance that affects one or more properties of composite material, particularly adhesion.

**Continuous filament** - Individual, small-diameter reinforcement that is flexible and indefinite in length.

**Continuous roving** - Large bundle of parallel filaments coated with sizing, gathered together into single or multiple strands, and wound into a cylindrical package. May be used to provide continuous reinforcement in woven roving, filament winding, pultrusion, prepregs, or high-strength molding compounds (may also be used chopped).

**Coordinate axes** - See laminate coordinate axes.

**Core** - In sandwich construction, the central component to which inner and outer skins are attached; also refers to a section of a complex mold that forms undercut parts.

**Core crush** - Compression damage of the core.

**Core depression** - Gouge or indentation in the core material.

**Core orientation** - Used on a honeycomb core to line up the ribbon direction, thickness of the cell depth, cell size and transverse direction.
Core splicing - Joining of two core segments by bonding them together.

**Cowoven fabric** - Reinforcement fabric woven with two different types of fibers in individual yarns (for example, thermoplastic fibers woven side by side with carbon fibers).

**Crazing** - Region of ultrafine cracks that may develop on or under a resin surface.

**Creep** - Time-dependent dimensional change in a material under physical load.

**Crimp** - Degree of waviness of a fiber, which determines its capacity to cohere.

**Critical length** - Minimum length of a fiber necessary for matrix shear loading to develop ultimate fiber strength.

**Cross-laminated** - Laminated with some of the layers oriented at one or more angles to the other layers with respect to the principal laminate axis.

**Crossply laminate** - Laminate having plies oriented only at 0° and 90°. May or may not be symmetric.

**Crosslinking** - Polymerization reactions that branch out from the main molecular chain to form a networked pattern of chemical links.

**Crystalline** - Having a molecular structure in which the atoms are arranged in an orderly, three-dimensional pattern.

**CTE** - See coefficient of thermal expansion.

**Cure** - To change the physical properties of a material irreversibly by chemical reaction via heat and/or catalysts, with or without pressure.

**Cure temperature** - Temperature at which a material attains final cure.

**Curing agent** - Catalytic or reactive agent that brings about polymerization when added to a resin.

**CVD** - See chemical vapor deposition.

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## D

**Damage tolerance** - Measure of the ability of structures to retain load-carrying capability after exposure to sudden loads (for example, ballistic impact).

**Damping** - Diminishing the intensity of vibrations.

**Debond** - Deliberate separation of a bonded joint or interface, usually for repair or rework purposes. (See also disbond.)

**Delamination** - Separation of plies in a laminate due to adhesive failure. This may be local or may cover a large area. Also includes the separation of layers of fabric from the core structure.

**Demold** - To remove a part from a tool, or a tool from an intermediate model.

**Denier** - Numbering system for continuous yarn and continuous filaments in which the yarn number is equal to the weight in grams per 9,000 meters of yarn; the finer the yarn, the lower the denier.

**Design allowable** - Limiting value for a material property that can be used to design a structural or mechanical system to a specified level of success with a specific level of statistical confidence.

**Dielectric** - Nonconductor of electricity; the ability of a material to resist the flow of an electric current.

**Disbond** - Unplanned non-adhered or unbonded area within a bonded interface. Can be caused by adhesive or cohesive failure, may occur at any time during the life of the structure and may arise from a wide variety of causes. The term is also sometimes used to describe a delamination.

**Doubler** - Extra layers of reinforcement for added stiffness or strength in laminate areas that incur abrupt load transfers.

**Drape** - The ability of prepreg to conform to the shape of a contoured surface.

**Dry winding** - A filament-winding operation in which resin is not used.

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## E

**E-glass** - Denotes "electrical glass," so called because of its high electrical resistivity. Refers to borosilicate glass fibers most often used in conventional polymer matrix composites.

**Elasticity** - The property of materials to recover immediately their original size and shape when load is removed after deformation.

**Elongation** - The fractional increase in length of a material loaded in tension. When expressed as a percentage of the original length, it is called percent elongation.

**End** - General term for a continuous, ordered assembly of essentially parallel, collimated filaments, with or without twist.

**Epoxy** - Thermoset polymer containing one or more epoxide groups, curable by reaction with amines or other compounds.

**Exotherm** - Heat released during a chemical reaction. Uncontrolled exotherm can lead to extreme heat build up and possibly violent explosion.

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## F

**Fabric** - Planar textile. Also known as cloth.

**Fabric, nonwoven** - Planar textile constructed by bonding or interlocking, but not interlacing, by mechanical, chemical, thermal or solvent means.

**Fabric, woven** - Planar textile constructed by interlacing in a weaving process.

**Fabrication** - Process of making a composite part or tool.

**Fatigue** - Failure or deterioration of a material's mechanical properties as a result of repeated cyclic loading or deformation over time.

**Fatigue strength** - Maximum cyclical stress withstood for a given number of cycles before a material fails. The residual strength after being subjected to fatigue loading.

**FEA** - Finite-element analysis.

**Fiber** - One or more filaments in an ordered assemblage.
Fiber architecture - Design of a fibrous preform or part in which the fibers are arranged (braided, stitched, woven, etc.) in a particular way to achieve the desired result.

**Fiber content** - Amount of fiber present in a composite expressed either as a percent by weight or percent by volume. Also sometimes stated as a fiber volume fraction.

**Fiber orientation** - Direction of fiber alignment in a nonwoven or mat laminate wherein most of the fibers are placed in the same direction to afford greater strength in that direction.

**Fiber placement** - Continuous process for fabricating composite shapes with complex contours and/or cutouts by means of a device that lays preimpregnated fibers (in tow form) onto a nonuniform mandrel or tool. Differs from filament winding in several ways: There is no limit on fiber angles; compaction takes place online via heat, pressure or both; and fibers can be added and dropped as necessary. The process produces more complex shapes and permits a faster putdown rate than filament winding.

**Fiber-reinforced plastics (FRP)** - General term used for a polymer-matrix composite that is reinforced with cloth, mat, strands or any other

fiber form. Often used to designate mid-range, glass-fiber reinforced composites.

**Fiber volume fraction** - See fiber content.

**Filament** - Polycrystalline or amorphous individual fiber unit with a length-to-diameter ratio greater than one. The minimum diameter of a filament is not limited, but the maximum diameter may not exceed 0.010 inches. Filaments greater than about 0.002 inches in diameter are often referred to as wires.

**Filament count** - Number of filaments in the cross-section of a fiber bundle.

**Filament winding** - Process of fabricating composites in which continuous reinforcing fibers, either preimpregnated with resin or drawn through a resin bath, are wound under controlled tension around a rotating form to make a structure. (See also winding, mandrel.)

**Fill** - Fiber bundles in a woven fabric that run transverse to the warp yarns; also known as weft or woof.

**Filler** - Solid constituent, usually inert, added to the matrix to modify the composite properties - such as increase viscosity, improve appearance or lower density - or to lower cost.

**Filler ply** - Additional patch to fill in a depression in repair or to build up an edge.

**Film adhesive** - Adhesive in the form of a thin, dry resin film with or without a carrier; commonly used for adhesion between laminate layers.

**Finish** - Material applied to textiles to improve the bond between the fiber and matrix; applied after sizing is removed.

**Finite element analysis** - Process of selecting the optimum combination of materials in a composite based on computational modeling and analysis.

**Flexural modulus** - Ratio, within the elastic limit, of the applied stress on a test sample in flexure to the corresponding strain in the outermost fibers of the sample.

**Flexural strength** - Strength of a material in bending, usually expressed in force per unit area, as the stress of a bent test sample at the instant of failure.

**Fracture** - Rupture of the surface of a laminate due to external or internal forces; may or may not result in complete separation.

**Fracture toughness** - Measure of the damage tolerance of a material containing initial flaws or cracks.

**FRP** - Fiber-reinforced plastic.

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## G

**Gel time** - Period of time from initial mixing of liquid reactants to the point when gelation occurs as defined by a specific test method.

**Glass transition** - Reversible change in an amorphous polymer between a viscous condition and a hard, relatively brittle condition.

**Glass-transition temperature (Tg)** - Approximate temperature at which increased molecular mobility results in significant changes in properties of a cured resin. The measured value of Tg can vary, depending on the test method.

**Graphitization** - Process of pyrolysis at very high temperatures (up to 5,400°F) that converts carbon to its crystalline allotropic form.

**Graphite fibers** - Carbon fiber that has been graphitized by heating and stretching at temperatures above 3,000°F.

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## H

**Hand layup** - Fabrication method in which reinforcement layers, preimpregnated or coated afterwards, are placed in a mold by hand, prior to cure to the formed shape.

**Hard tool** - Tool made of metal or any "hard" material that is generally impervious to damage during normal use.

**Hardener** - Substance used to promote or control curing action by participating in and being consumed by the cure reaction. (See also catalyst.)

**Heat** - Term used colloquially to indicate any temperature above ambient (room) temperature to which a part or material is or will be subjected.

**Heat-distortion temperature (HDT)** - Temperature at which deflection occurs under

specified temperature and stated load.

**Helical** - Ply laid onto a mandrel at an angle, often at a 45° angle.

**High-performance composites** - Composites offering properties better than conventional structural metals, typically on a strength-to-weight or stiffness-to-weight basis. Such composites use continuous, oriented fibers in polymer, metal or ceramic matrices to achieve their superior properties.

**Honeycomb** - Resin-impregnated material, most commonly manufactured in hexagonal cells, that serves as a core in sandwich structure. May also be a metal or a polymer in rigid, open-cell structure.

**Hoop** - Ply laid onto a mandrel at a 90° angle.

**Hoop stress** - Circumferential stress in a cylindrically shaped part as a result of internal or external pressure.

**Hot-bond repair** - Repair made on a hot-patch bonding machine to cure and monitor curing. Typically includes heat and vacuum source.

**Hybrid composite** - Composite containing at least two distinct types of matrix or reinforcement. The matrix or reinforcement types can be distinct because of their physical properties, mechanical properties, material form and/or chemical composition.

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## I

**Impact strength** - A material's ability to withstand shock loading as measured by fracturing a specimen.

**Impregnate** - To saturate the voids and interstices of a reinforcement with a resin.

**Impregnated fabric** - See prepreg.

**Inclusion** - Physical and mechanical discontinuity occurring within a material or part.

**Integral heating** - System in which heating elements are built into a tool, forming part of the tool and usually eliminating the need for an oven or autoclave as a heat source.

**Interface** - Surface between two materials: in glass fibers, for instance, the area at which the glass and

sizing meet; in a laminate, the area at which the reinforcement and laminating resin meet.

**Interlaminar** - Existing or occurring between two or more adjacent laminae in a laminate.

**Interlaminar shear** - Shearing force that produces displacement between two laminae along the plane of their interface.

**Intralaminar** - Existing or occurring within a single lamina in a laminate.

**Isotropic** - Fiber directionality with uniform properties in all directions, independent of the direction of applied load.

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## J

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## K

**Kevlar** - Trademark of DuPont for high-performance para-aramid fibers used as reinforcements.

**Knit** - Textile process that interlocks, in a specific pattern, loops of yarn by means of needles or wires.

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## L

**Lamina** - Subunit of a laminate consisting of one or more adjacent plies of the same material with identical orientation.

**Lamina orientation** - See ply orientation.

**Laminate** - Any fiber- or fabric-reinforced composite consisting of laminae with one or more orientations with respect to some reference direction.

**Laminate coordinate axes** - Set of coordinate axes, usually right-handed Cartesian, used as a reference in describing the directional properties and geometrical structure of the laminate. Usually the x-axis and the y-axis lie in the plane of the laminate and the x-axis is the reference axis from which ply angle is measured. The x-axis is often in the principal load direction of the laminate and/or in the direction of the laminate principal axis. (See also principal axis, off-axis laminate, x-axis.)

**Layup** - Process of placing layers of reinforcing material placed in position in the mold. The

reinforcing materials placed in the mold.

**Layup code** - Designation system for abbreviating the stacking sequence of laminated composites.

**Liquid-crystal polymers (LCP)** - High-performance melt-processible thermoplastics that develop high orientation in the melt and after molding, resulting in very high tensile strength and high-temperature capability.

**Lot** - See batch.

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## M

**Mandrel** - A form, fixture or male mold used as the base for production of a part in processes such as lay-up or filament winding.

**Mat** - An unwoven textile fabric made of fibrous reinforcing material such as chopped filaments (to produce chopped-strand mat) or swirled filaments (to produce continuous-strand mat) with a binder applied to maintain form. Available in blankets of various widths, weights, thicknesses and lengths. May be oriented.

**Matrix** - Material in which reinforcing fiber of a composite is imbedded: polymer, metal or ceramic.

**Matrix content** - Amount of matrix present in a composite expressed either as a percent by weight or percent by volume. For polymer-matrix composites this is the resin content. (See also fiber content.)

**Metal-matrix composites (MMC)** - Continuous carbon, silicon carbide, or ceramic fibers embedded in a metallic matrix material.

**Midplane** - Plane that is equidistant from both surfaces of the laminate.

**Microcracking** - Microscopic cracks formed in composites when thermal stresses locally exceed the strength of the matrix.

**MMC** - Metal-matrix composite.

**Modulus** - Measure of the ratio of applied load (stress) to the resultant deformation of a material. May be represented by a number or in descriptive terms as low, intermediate, high or ultrahigh. (See also stiffness, Young's modulus.)

**Moisture absorption** - Pickup of water vapor from

the air by a material. Refers to vapor withdrawn from the air only as distinguished from water absorption, which is weight gain due to the absorption of water by immersion.

**Monomer** - A single molecule that reacts with like or unlike molecules to form a polymer.

**Monofilament** - Single continuous filament strong enough to function as a fiber in textile or other operations.

**Multifilament** - Yarn or tow consisting of many continuous filaments.

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## N

**NDE, NDI, NDT** - Non-destructive evaluation, non-destructive inspection, non-destructive testing.

**Near-net shape** - Part fabrication resulting in final dimensions that require minimal machining, cutting or other finishing.

**Net shape** - Part fabrication resulting in final dimensions that do not require machining or cutting.

**Nomex** - Trademark of DuPont for moderate-performance meta-aramid material that is often used in paper-form to make honeycomb core.

**Nondestructive inspection (NDI)** - Determining material or part characteristics without permanently altering the test object. Nondestructive testing (NDT) and nondestructive evaluation (NDE) are broadly considered synonymous with NDI.

**Nonwoven roving** - Reinforcement composed of continuous rovings loosely gathered together.

Off-axis laminate - Laminate whose principal axis is oriented at an angle theta other than 0° or 90° with respect to a reference direction, usually related to the principal load or stress direction.

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## O

**One-off** - Fabrication process in which a single part is fabricated.

**One-part resin system** - Resin system (often used in resin transfer molding) in which the neat resin and catalyst are mixed together by the materials supplier as part of the resin production operation.

**Original equipment manufacturer (OEM)** - Companies that design and build products bearing their name, such as Boeing 777 aircraft or Prince tennis racquets.

**Out time** - Period of time in which a prepreg remains handleable with properties intact outside a specified storage environment (such as a freezer, in the case of thermoset prepregs).

**Outgassing** - Release of solvents and moisture from composite parts under the hard vacuum of space.

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## P

**PAN** - Same as polyacrylonitrile.

**Part consolidation** - Process of composites fabrication in which multiple discrete parts are designed and fabricated together into a single part, thus reducing the number of fabricated parts and the need to join those parts together.

**Peel ply** - Layer of material applied to a prepreg layup surface that is removed from the cured laminate prior to bonding operations, leaving a clean, resin-rich surface ready for bonding.

**Peel strength** - Strength of an adhesive bond obtained by stress that is applied in a "peeling" mode.

**Phenolic resin** - Thermosetting resin produced by a condensation reaction of an aromatic alcohol with an aldehyde (usually phenol with formaldehyde).

**Pin holes** - Small holes that penetrate the surface of a cured part.

**Pitch** - Residual petroleum product used as a precursor in the manufacture of certain carbon fibers.

**Planar winding** - Filament winding in which the filament path lays on a plane that intersects the winding surface.

**Plied yarn** - Two or more yarns collected together with or without twist.

**Ply** - Constituent single layer used in fabricating or occurring within a composite structure. Also, the number of single yarns twisted together to form a plied yarn.

**Ply orientation** - Acute angle (theta) - including 90° - between a reference direction and the ply principal axis. The ply orientation is positive if measured counterclockwise from the reference direction and negative if measured clockwise.

**Ply schedule** - Layup of individual plies or layers to form a laminate. Plies may be arranged in alternating fiber orientation to produce multidirectional strength in a part.

**Polar winding** - Filament winding in which the filament path passes tangent to the polar opening at one end of the chamber and tangent to the opposite side of the polar opening at the other end of the chamber.

**Polyacrylonitrile (PAN)** - Base material in the manufacture of some carbon fibers.

**Polyimide** - Highly heat-resistant polymer resin.

**Polymer** - Large organic molecule formed by combining many smaller molecules (monomers) in a regular pattern.

**Polymerization** - Chemical reaction that links monomers to form polymers.

**Porosity** - Presence of visible voids within a solid material into which either air or liquids may pass.

**Postcure** - Additional exposure to elevated temperature, often occurring without tooling or pressure, that improves mechanical properties.

**Pot life** - Length of time in which a catalyzed thermosetting resin retains sufficiently low viscosity for processing.

**Precure** - Full or partial setting of a resin or adhesive before the clamping operation is complete or before pressure is applied.

**Precursor** - Material from which carbon fiber is made by pyrolysis. Common precursors are polyacrylonitrile (PAN), rayon and pitch. **Preform** - Pre-shaped fibrous reinforcement, normally without matrix, but often containing a binder to facilitate manufacture; formed by distribution of fibers to the approximate contour and thickness of the finished part, typically on a mandrel or mock-up.

**Prepreg** - Admixture of fibrous reinforcement and polymeric matrix used to fabricate composite materials in a form that can be stored for later use.

It may be sheet, tape, tow or fabric. For thermosetting matrices the resin is usually partially cured or otherwise brought to a controlled viscosity, called B-stage. Additives such as catalysts, inhibitors and flame retardants can be added to obtain specific end-use properties and improve processing, storage and handling characteristics.

**Primary structure** - An aerospace critical load-bearing structure; if damaged the air- or spacecraft cannot fly.

**Prime contractors** - Referred to as "primes"; companies that are awarded government contracts and usually work with subcontractors (or "subs") who provide individual and specific components or systems relevant to the contract. Primes often team on contracts, sharing portions of the contract funding.

**Principal axis** - Laminate coordinate axis that coincides with the direction of maximum inplane Young's modulus. Within a ply, for a balanced weave fabric either warp or fill direction may be chosen. (See also laminate coordinate axes and x-axis.)

**Prototype** - Process of creating a test part not intended for commercial release that establishes design, material and fabrication parameters for a new product. May entail multiple iterations to arrive at final/commercial part design.

**Puckers** - Local areas on prepreg where material has blistered and pulled away from the separator film or release paper.

**Pultrusion** - Continuous process for manufacturing composites in rods, tubes and structural shapes having constant cross sections. After the reinforcement is passed through the resin-impregnation bath, it is drawn through a shaping die to form the desired cross section; curing takes place before the laminate can depart from that cross section.

**Puncture** - Break in composite skin in sandwich structure that may or may not go through to the core material or completely through the part.

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## Q

**Quadraxial fabric** - Fabric with four non-interwoven layers - +45°, -45°, 0° and 90°, - which are bonded together, usually by through-the-thickness stitching, to form a single sheet of fabric.

(See also biannual fabric, triaxial fabric.)

**Quasi-isotropic laminate** - A laminate approximating isotropy by orientation of plies in several or more directions.

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## R

**Ramping** - Gradual programmed increase/ decrease in temperature or pressure to control cure or cooling of composite parts.

**Rate tools** - Tools designed to be used repeatedly in a production setting to fabricate many parts rather than a single prototype or small number of demonstration parts.

**Reinforcement** - Key element added to the matrix to provide the required properties (primarily strength); ranges from short fibers through complex textile forms.

**Release agent** - Used to prevent cured matrix material from bonding to tooling; usually sprayed or painted on mold.

**Release film** - Impermeable film layer that does not bond to the composite during cure.

**Resin** - Solid polymeric material, often of high molecular weight, which exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally. As composite matrices, resins bind together reinforcement fibers.

**Resin content** - See matrix content.

**Resin-rich** - Filled with excess resin and thus departing from a consistent resin/fiber ratio.

**Resin-starved** - Lacking sufficient resin for fiber wetout.

**Resin transfer molding (RTM)** - Molding process in which catalyzed resin is transferred into an enclosed mold into which a fibrous reinforcement has been placed. The mold and/or resin may or may not be heated. RTM combines relatively low tooling and equipment costs with the ability to consolidate large structural parts.

**Ribbon direction** - On a honeycomb core, the way the honeycomb can be separated. The direction of one continuous ribbon.

**Roving** - Large filament-count tow.

**RTM** - See resin-transfer molding.

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## S

**S-glass** - Denotes "structural glass" a magnesia/alumina/silicate glass reinforcement designed to provide very high tensile strength. Used in high-performance composites.

**Sandwich structure** - Composite composed of lightweight core material (usually honeycomb or foam) to which two relatively thin, dense, high-strength, functional or decorative skins are adhered.

**Scrim** - Low-cost, woven reinforcing fabric in an open mesh construction.

**Sealant** - Paste or liquid applied to a joint that hardens in place to form a seal.

**Secondary structure** - Aerospace structure that is not critical to flight safety.

**Shear** - Action or stress resulting from applied forces that causes or tends to cause two contiguous parts of a body to slide relative to each other.

**Shelf life** - Length of time in which a material can be stored and continue to meet specification requirements, remaining suitable for its intended use. (See also storage life.)
Silicon carbide fiber - Reinforcing fiber with high strength and modulus; density is equal to that of aluminum. May be formed as wires by chemical vapor deposition onto a carbon-filament core, or as filaments. Used in both organic and metal-matrix composites.

**Size** - Material applied to textiles to facilitate subsequent operations such as weaving or braiding. Sizes may be used to bind together and stiffen warp yarns during weaving and/or to minimize abrasion and wear. Sizes are usually removed and replaced with finish before matrix application. Also called sizing.

**Skin** - Layer of relatively dense material used on the surface of the core of a sandwich structure.

**Soft tool** - Tool made of composites or a similar "soft" material that is vulnerable to damage during use, storage or transportation.

**Solvent** - Liquid used to dissolve and clean

materials.

**Spec** - Specification of the properties, characteristics, or requirements a particular material or part must have in order to be acceptable to a potential user of the material or part.

**Specific gravity** - Density (mass per unit volume) of a material divided by that of water at a standard temperature.

**Stacking sequence** - Arrangement of ply orientations and material components in a laminate specified with respect to some reference direction.

**Staple** - Collection of short filaments of spinnable length.

**Stiffness** - Measure of the resistance of a material to deformation. The ratio of applied stress to resulting strain for a particular material.

**Storage life** - Amount of time a material can be stored and retain specific properties. (See also shelf life.)

**Strain** - Deformation resulting from applied stress. Measured as the change in length per unit of length in a given direction, and expressed in percentage or as inches per inch.

**Strand** - See tow.

**Stress** - Internal resistance to change in size or shape, expressed in units of force (load) per unit area.

**Stress concentration** - Magnification of applied stress in the region of a notch, void, hole or inclusion.

**Stress crack** - External or internal cracks in a composite caused by tensile stresses; cracking may be present internally, externally or in combination.

**Structural adhesive** - Adhesive used to transfer loads between adherents.

**Structural bond** - Bond joining load-bearing components of an assembly.

**Structural repair manual (SRM)** - Document prepared by an OEM that designates original structural materials (both composite and metal) used for a specific aircraft. It usually includes schematics for all parts and listings of fastener types and adhesives. It also suggests general repair

methodology so that structural integrity can be maintained, including whether autoclave cure is required. Updated periodically by OEMs based on input from repair technicians.

**Substrate** - Material upon the surface of which an adhesive-containing substance is spread for any purpose, such as bonding or coating.

**Symmetric laminate** - Laminate in which the stacking sequence for the plies located on one side of the geometric midplane are the mirror image of the stacking sequence on the other side of the midplane.

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## T

**Tack** - Stickiness of an uncured prepreg.

**Tape** - Thin unidirectional prepreg in widths up to 12 inches for carbon fiber.

**Tensile strength** - Maximum tensile stress sustained by a specimen before it fails in a tension test.

**Tg** - Glass-transition temperature.

**Thermal conductivity** - Ability to conduct heat.

**Thermal stress cracking** - Crazing and cracking of some thermoplastic resins from overexposure to elevated temperatures.

**Thermocouple** - Wire assembly used with a control device to sense temperature readings.

**Thermoplastic** - Class of plastics that can be repeatedly softened by heating and hardened by cooling through a temperature range characteristic of the plastic, and that in the softened state can be shaped by flow into articles by molding or extrusion.

**Thermoset** - Class of plastics that, when cured using heat, chemical or other means, changes into a substantially infusible and insoluble material. Once cured, a thermoset cannot be returned to the uncured state.

**Thixotropic** - Substance that is gel-like at rest, but fluid when agitated, and thus can be applied easily but clings to a vertical surface. Thixotropic substances have high static shear strength and low dynamic shear strength at the same time, and lose viscosity under stress.

**Tool** - The mold, either one- or two-sided and either open or closed, in or upon which composite material is placed in order to make a part.

**Tooling resins** - Plastic resins, chiefly epoxy and silicone, that are used as tooling aids.

**Toughness** - Measure of the ability of a material to absorb energy.

**Tow** - Continuous, ordered assembly of essentially parallel, collimated filaments, normally continuous filaments without twist. Same as strand.

**Tow size** - Designation indicating the number of filaments in a tow, usually a number followed by K, indicating multiplication by 1,000 (for example, 12K tow has 12,000 filaments).

**Triaxial fabric** - Fabric with three non-interwoven layers - +45°, - 45° and either 0° or 90° - which are bonded together, usually by through-the-thickness stitching, to form a single sheet of fabric. (See also biaxial fabric, quadraxial fabric.)

**Twist** - Measure of the number of turns per unit length that a fiber bundle makes around its axis. "Z"-twist denotes a right-handed twist, while "S"-twist denotes a left-handed twist. "U" is often used to represent no twist and "N" means never twisted.

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## U

**Unidirectional (UD)** - Referring to fibers that are oriented in the same direction, such as unidirectional fabric, tape or laminate.

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## V

**Vacuum-bag molding** - Molding technique wherein the part is cured inside a layer of film from which entrapped air is removed by vacuum.

**Viscosity** - Tendency of a material to resist flow. Viscosity is measured in comparison with water. The higher the number, the less flow.

**Void** - Any pockets of enclosed gas or air within a composite.

**Volatiles** - Materials, such as water and alcohol, in a sizing or resin formulation that can be vaporized at room or slightly elevated temperatures.

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# TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

| | |
|---|---|
| Application Number | 10/662,743 |
| Filing Date | September 15, 2003 |
| First Named Inventor | Elbert L. McKague, Jr. |
| Art Unit | 1771 |
| Examiner Name | Andrew L. Piziali |
| Attorney Docket Number | TA-00491C |
| Total Number of Pages in This Submission | 50 |

## ENCLOSURES (Check all that apply)

- [x] Fee Transmittal Form
  - [ ] Fee Attached
- [x] Amendment/Reply
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
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  - [ ] Reply to Missing Parts under 37 CFR 1.52 or 1.53
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## W

**Warp** - Fiber bundles in a woven fabric that run parallel to the length of the loom, lengthwise along the long-dimension of the fabric.

**Warpage** - Dimensional distortion in a composite part.

**Water absorption** - Ratio of weight of water absorbed by a material to the weight of dry material.

**Water jet** - High-pressure water stream used for cutting polymer composite parts.

**Weave** - Fabric pattern formed from interlacing yarns. In plain weave, warp and fill fibers alternate to make both fabric faces identical. A satin weave pattern is produced by a warp tow over several fill tows and under one fill tow (for example, eight-harness satin would have one warp tow over seven fill tows and under the eighth).

**Weft** - See fill.

**Wet layup** - Application of a resin to a dry reinforcement in the mold.

**Wet winding** - Filament winding wherein fiber strands are impregnated with resin immediately before contact with the mandrel.

**Wetout** - Saturation with resin of all voids between strands and filaments.

**Wetting agent** - Surface-active agent that promotes wetting by decreasing the cohesion within a liquid.

**Wind angle** - Measure in degrees between the direction parallel to the filaments and an established reference point.

**Winding** - Process in which continuous material is applied under controlled tension to a form in a predetermined geometric relationship to make a structure. A matrix material to bind the fibers together may be added before, during or after winding. Filament winding is the most common type.

**Winding pattern** - In filament winding, recurring pattern of the filament path after a certain number of mandrel revolutions.

**Wire** - Large diameter (greater than about 2 mils)

high-performance fiber, such as boron or silicon carbide, usually made by chemical vapor deposition onto a filamentary substrate.

**Wire mesh** - Fine wire screen used to dissipate the electrical charge from lighting.

**Woof** - Same as fill.

**Woven roving** - Heavy, coarse fabric produced by weaving continuous roving bundles.

**Wrinkle** - Imperfection in the surface of a laminate that looks like a crease in one of the outer layers. This occurs in vacuum-bag molding when the bag is improperly placed.

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## X

**X-axis** - Usually, the axis in the plane of the laminate used as 0° reference. Typically, the y-axis is the axis in the plane of the laminate perpendicular to the x-axis, and the z-axis is the reference axis normal to the laminate plane in the composite laminate. (See also laminate coordinate axes, off-axis laminate and principal axis.)

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## Y

**Y-axis** - See x-axis.

**Yarn** - Continuous, ordered assembly of essentially parallel, collimated filaments, usually with a twist.

**Young's modulus** - Ratio of normal stress to the corresponding strain for tensile or compressive stresses less than the proportional limit of the material.

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## Z

**Z-axis** - See x-axis.

**Zero bleed** - Laminate fabrication procedure that does not allow loss of resin during cure.